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HETEROSIS AND COMBINING ABILITY ANALYSIS OF QUANTITATIVE AND QUALITATIVE TRAITS IN MUSKMELON (*CUCUMIS MELO* L.)

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ABSTRACT

Combining ability analysis was conducted to understand the nature of gene action of quantitative traits and to identify promising parents for breeding programme in muskmelon. Six female and five male parents were crossed in line x tester mating fashion to produce thirty F_1s and were grown in a randomized complete block design with three replications. Analysis of variance showed high magnitude of GCA over SCA variance indicating predominance of additive gene effects for all the traits. RM 43 and IIHR122 were the best general combiner for most of the quantitative traits. Strong phenotypic correlation between GCA and parent per se performance for all traits except for number of primary branches per vine and fruit yield per vine indicated the possibility of selection of traits at the level of parents. Hybrids ms-1 x IIHR 616, RM 43 x IIHR 718 and RM 43 x IIHR 121 out yielded commercial check NS 910 with significantly larger fruits, significantly more sweeter and earlier in picking could be commercially viable for hybrid seed production as they involved male sterile (ms-1) and monoecious (RM 43) lines as female parent.

KEYWORDS: Muskmelon, Cucumis Melo, Heterosis, Combining Ability, Quantitative Traits

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INTRODUCTION

Muskmelon (*Cucumis melo* L.) is an important member of cucurbitaceous family has numerous uses. The species *Cucumis melo* is a large polymorphic group comprising a large number of botanical and horticultural varieties. The edible portion of the muskmelon is rich in vitamin A, carbohydrates and fibres. The fruits are highly relished because of their attractive flavour, sweet taste and refreshing effect. Immature fruits may be used fresh in salads, cooked or pickled. The fruit juice is nutritive, diuretic, demulcent and aphrodisiac. The seed oil is useful in painful discharge and suppression of urine (Nadakarni, 1929).

Heterosis for earliness, fruit size, fruit weight, flesh thickness, total soluble solids and yield and its associated components has been observed in muskmelon (Scott 1933; Bohn and Davis 1957; Foster 1967; Lippert and Hall 1982; McCreight *et al*. 1993; Dhaliwal 1995; Munshi & Verma 1997; Abdalla and Aboul-Nasr 2002; Moon *et al*. 2003). Combining ability studies for earliness, fruits quality traits, yield and yield related traits in muskmelon are common (Lippert and Legg 1972; Chadha and Nandpuri 1980, Dhaliwal and Lal 1996; Munshi and Verma 1999; Gurav *et al*. 2000; Zalapa *et al*. 2006).

In the present study, one male sterile (*ms*-1), two monecious and three andromonoecious lines were used as female parents and five male parents were crossed in line x tester mating fashion. The aim of this study was to classify parental genotypes and their hybrids relative to the combining ability effects for important quantitative traits. Such classification would help identify good general combiners to be used as donor parents for the

improvement of the important traits and specific cross combinations for the utilization of heterosis effect through the development of hybrid and/or isolation of superior segregates in advance generations of segregation.

MATERIAL AND METHODS

Plant Materials

The parents were inbred lines maintained by continuous 15-20 self-pollinations at the Indian Institute of Horticultural Research, Bangalore were used to study combining abilities for important quantitative traits. Parents were selected based on the field performance to yield and other important traits. The set of six female parents (lines) included RM 43 (monoecious), IIHR 352 (monoecious), *ms*-1 (male sterile), Arka Jeet (andromonoecious), Punjab Sunehri (andromonoecious) and IIHR 681 (andromonoecious). The set of five male parents (testers) included IIHR 616, IIHR 190, IIHR 718, IIHR 121 and IIHR 122. Thirty hybrids involving six female and five male parents were produced in line x tester mating design. Mean performance of six lines and five testers for all the traits are presented Table 1.

Experimental Plan

Seedlings of eleven parents and their thirty hybrids were raised in 50-unit plastic potting trays inside greenhouse. At two-three leaf stage, seedlings were transplanted to the main field on raise beds at Vegetable Block, Indian Institute of Horticultural Research, Bangalore. To take observation individual seedling was spaced at 3.0 m between beds (centre to centre) and 0.45 m within bed. Field plots with 15 plants each arranged in three randomized blocks. Each parent and F_1 hybrid planted one plot per block.

Data Collection

Data for seven quantitative traits were recorded on five plants in each replication. Days to anthesis was taken as number of days counted from the date of planting to the onset of first fully opened male flower. Days to first fruit harvest was counted from the date of planting to the onset of first fruit harvest. Number of primary branches per vine was counted at the final harvest. Few drops of juice extracted from the ripe fruit were used to determine the total soluble solids with the help of Erma (0 to 32%) hand refractometer and the values were noted in per cent (%). The ratio of total weight of fruits divided by total number of fruits per vine gave the average fruit weight and expressed in kilograms. The total number of fruits per vine of all the harvests were recorded and counted as number of fruits per vine. The weight of fruits from each harvest was recorded and fruit yield per vine was recorded and expressed in kilograms (kg).

The data were analyzed as per the line x tester method suggested by Kempthorne (1957) using the model proposed by Arunachalam (1974) and described by Singh and Choudhary (1985). Using expected mean sum of squares, the formulae for covariance of half sibs and full sibs that in turn give the variances due to general combining ability (GCA) and specific combing ability (SCA). The sum squares for genotypes were subdivided into variation among parents, variation among hybrids and variation among parents *vs.* hybrids. The sum of squares for parents was subdivided into variation among lines *vs*. testers, variation among lines and variation among testers. Statistical analysis was computed by using SPAR1 program (Indian Agricultural Research Institute, New Delhi).

Simple correlation coefficients were calculated between parents and progenies. GCA of all eleven parents was correlated to all parents *per se* values to calculate GCA-*per se* correlation. Averages of all thirty hybrids were correlated to all mid-parent values to calculate midparent-hybrid correlation. Averages of all thirty hybrids were correlated to SCA effects of all the hybrids to calculate SCA-hybrid *per se* correlation.

RESULTS

Analysis of Variance

Analyses of variance of thirty hybrids and eleven parents showed that mean square due to all sources of variation for all the quantitative traits (Table 1) were significantly different.

General Combining Ability Effects

The GCA effects of the eleven parents for seven quantitative traits are presented in Table 2. In the present study, no parent exhibited superior GCA for all the characters indicating random genetic variability among the parents. Negative GCA effects are preferred for earliness and positive GCA effects for other traits. Punjab Sunehri was best highest GCA effects for days to anthesis and average fruit weight, Arka Jeet for days to first fruit harvest, IIHR 616 for number of primary branches per vine, IIHR 122 for total soluble solids, IIHR 681 for number fruits per vine and RM 43 for fruit yield per vine.

Specific Combining Ability Effects

Estimates of SCA of thirty crosses for seven quantitative traits are presented in the Table 3. In the present study, none of the crosses showed high SCA for all the traits. But three crosses *viz*. *ms*-1 x IIHR 190, IIHR 681 x IIHR 122 and IIHR 352 x IIHR 718 expressed significant and negative SCA effects for both days to anthesis and days to first fruit harvest. Twelve crosses showed significant and negative SCA effects for days to first fruit harvest with highest SCA effect recorded in the cross PS x IIHR 190 followed by PS x IIHR 616, Arka Jeet x IIHR 121 and IIHR 681 x IIHR 122.

Eight crosses exhibited significant and positive SCA effects for number of primary branches per vine with highest SCA effects in the cross *ms*-1 x IIHR 190 followed by IIHR 352 x IIHR 616 and IIHR 352 x IIHR 121. High, significant and positive SCA effects for total soluble solids was detected in seven crosses *viz*. PS x IIHR 190, RM 43 x IIHR 121, *ms*-1 x IIHR 616, *ms*-1 x IIHR 190, *ms*-1 x IIHR 121, IIHR 681 x IIHR 190 and IIHR 352 x IIHR 616. Nine out of thirty crosses expressed significant and positive SCA effects with highest recorded in *ms*-1 x IIHR 616 followed by IIHR 352 x IIHR 190, Arka Jeet x IIHR 121. Seven crosses *viz*. Arka Jeet x IIHR 190, Arka Jeet x IIHR 122, RM 43 x IIHR 718, RM 43 x IIHR 121, IIHR 681 x IIHR 718, IIHR 352 x IIHR 616 and IIHR 352 x IIHR 718 exhibited significant and positive SCA effects for number of fruits per and fruit yield per vine.

Heterosis

Data on economic heterosis of selected hybrids are in Table 4. None of the hybrids was significantly superior to NS 910 for days to anthesis and number of primary branches per vine. However, five hybrids viz. Arka Jeet x IIHR 122, PS x IIHR 718, RM 43 x IIHR 718, RM 43 x IIHR 121 and *ms*-1 x IIHR 616 out yielded commercial variety NS 910 by atleast 16.78 % and upto 44.07 %. Estimates for average fruit weight, days to first fruit harvest and total soluble solids were significant and positive for these five hybrids.

Correlation between Parent and Progeny

Estimates of correlation between parent and progeny are presented in Table 5. Phenotypic correlations between mid-parent and hybrid performance were tight for all the traits except number of primary branches per vine and fruit yield per vine. Similarly, there was a close phenotypic correlation between GCA and parent *per se* performance for all the traits except number of primary branches per vine and fruit yield per vine. Correlation between SCA and hybrid *per se* was

moderate for days to first fruit harvest and average fruit weight.

DISCUSSIONS

Single degree of freedom comparison (parents *vs.* hybrids) which indicated average heterosis, was significant ($P < 0.01$) i.e. average of all thirty crosses is greater than average of all eleven parents for all the traits. Significant parent *vs*. hybrid and line *vs*. tester indicated the presence of non-allelic interactions. The magnitude of GCA variance was higher than SCA variance for all quantitative traits which indicated predominance of additive gene effects. These results are consistent with Lippert and Legg (1972), Dhaliwal and Lal (1996) and Zalapa *et al*. (2006) who evaluated gene action of yield traits in muskmelon and determined that both additive and non-additive variance components were important in the genetic control of yield associated traits. The GCA variance represents additive and additive x additive gene action, whereas variance due to SCA represents the dominance, additive x dominance and dominance x dominance gene action (Falconer 1996). For utilization of both additive and non-additive types of gene actions in these traits, reciprocal recurrent selection or diallel selective mating system could be followed.

RM 43 among lines and IIHR 121 and IIHR122 among testers were the overall best general combiners for many traits and progenies involving these parents could be used for biparental mating or multiple crosses to accumulate the favourable genes from two or more parents, followed by intermating among the selected segregates. Such approaches are likely to generate trangressive segregates, as were obtained in earlier studies (Bains and Kang 1963; Singh *et al*. 1976).

Most the hybrids which exhibited significant SCA in desirable direction had one or both parents with good GCA effects in all the traits. SCA effects and *per se* performance of hybrids were not positively correlated in all the crosses. However, highest SCA effects and highest *per se* performance were in accordance for all the quantitative traits except for number of primary branches per vine. Overall, the SCA-hybrid *per se* correlation was low-moderate for most of the traits indicating SCA effects were not in accordance with hybrid *per se* performance in of the most crosses and all quantitative traits. Therefore, crosses, which would give highest SCA effects, would not necessarily give the highest mean values in all the crosses. The high SCA effects detected in several crosses and GCA effects of their parents for different traits indicated that these cross combinations were result of good x poor and poor x poor combination. Thus, it was evident that a good x good combination not necessarily the result of good x good combination of parents. Such findings were also reported by Lippert and Legg (1972), Dhaliwal and Lal (1996), Munshi and Verma (1998) and Moon *et al*. (2004). Biparental progeny selection (Andrus 1963) might be used to get transgressive segregants from crosses involving good x good and good x poor combination of parents.

CONCLUSIONS

The efficiency of a hybrid breeding programme strongly depends on the correlation between the performance of parental lines, testcrosses and GCA. As a consequence of the close relationship between GCA and parent *per se* performance, all traits except for number of primary branches per vine and fruit yield per vine which can be preselected at the level of parents. The association between GCA effects and mean performance of the parents suggested that the *per se* performance could be a good indicator of its ability to transmit the desirable attributes to its progenies.

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APPENDICES

Table 1: Analysis of Variance for Parents, F_1 Hybrids and Interactions of Quantitative and Qualitativetraits in Muskmelon

Sources	D.F	Days to Anthesis	Days to First Harvest	No. of Primary Branches Per Vine	Total Soluble Solids	Average Fruit Weight	Number of Fruits per Vine	Fruit yield Yield
Treatment	40	8.81**	23.46**	0.32**	23.30**	0.55**	2.65**	2.08**
Replications	2	3.02	0.16	0.05	3.60	0.11	1.67	1.37
Parents	10	14.40**	24.38**	0.64**	17.17**	0.71**	2.22**	1.59**
Lines	5	16.24**	75.02**	0.58**	22.67**	1.23**	3.26**	2.46**
Testers	4	15.08**	5.75*	0.81**	112.45**	3.48**	31.64**	39.63**
Line x Testers	20	2.39**	2.71**	0.42**	7.89**	1.31**	2.91**	2.91**
Hybrids	29	6.33*	15.83**	0.28*	27.89**	2.24**	7.26**	2.59**
Parents *vs*. Hybrids	1	31.40**	272.86**	2.46**	103.52**	3.40**	2.84**	3.05**
Error	80	0.59	1.77	0.05	0.53	0.10	0.30	0.17
Variances								
σ^2GCA	-	0.74	2.09	0.04	2.13	0.08	0.10	0.18
σ^2SCA	-	0.61	0.31	0.02	0.38	0.05	0.04	0.16
σ^2GCA/ σ^2SCA	-	1.21	6.74	2.00	5.61	1.60	2.50	1.13

*, **: Significant at 5 % and 1 % probability level respectively.

Table 2: General Combining Ability (GCA) Effects of Parents of Quantitative and Qualitative Traits, in Muskmelon

Parents	Days to Anthesis	Days to First Harvest	No. of Primary Branches Per Vine	Total Soluble Solids	Average Fruit Weight	Number of Fruits per vine	Fruit yield Yield
Female							
Arka Jeet	–0.90**	–3.96**	0.24*	0.37	–0.09*	0.16*	–0.47**
Punjab Sunehri	–1.31**	–0.40	–0.06	0.51**	0.11**	–0.04*	0.24**
RM 43	–0.51*	0.46	–0.24**	0.87**	0.13**	0.76**	0.76**
ms-1	–0.05	–1.49**	0.14**	0.44	–0.12**	0.14*	–0.04

IIHR 681	0.79*	2.78**	0.10*	1.24**	–0.17**	0.80**	0.05
Table 2: Contd							
IIHR 352	1.74**	1.84**	–0.27**	-2.85**	0.19**	–1.23**	–0.13*
SE (g_i)	0.19	0.34	0.06	0.19	0.02	0.11	0.10
Male							
IIHR 616	–0.30	–0.11	0.34**	-0.03	0.18**	–0.29**	0.40**
IIHR 718	–0.58*	0.26	–0.04	-2.96**	–0.11**	–0.07	0.09
IIHR 190	0.77*	0.70**	–0.09	-1.14**	–0.17**	–0.40**	–0.06
IIHR 121	–0.91**	–0.16	–0.07	1.29**	–0.09*	–0.31**	–0.09
IIHR 122	1.02**	–0.70**	–0.14**	2.83**	–0.09*	0.44**	0.21**
SE (g_j)	0.16	0.29	0.05	0.16	0.12	0.10	0.09

*, **: Significant at 5 % and 1 % probability level respectively.

^{G}GCA effects for powdery mildew and downy mildew in greenhouse condition

Table 3: Estimates of SCA Effects of Quantitative and Qualitative Traits in Muskmelon

Cross	Days to Anthesis	Days to First Harvest	No. of Primary Branches per vine	Total Soluble Solids	Average Fruit Weight	Number of Fruits per vine	Fruit yield Yield
Arka Jeet x IIHR 616	–0.43*	–0.33	–0.11	0.07	–0.14	–0.19	–0.51**
Arka Jeet x IIHR 718	0.45*	0.39	0.22**	-0.02	–0.17*	–0.51**	–0.64**
Arka Jeet x IIHR 190	–0.41*	0.59*	0.02	0.26	0.12	0.88**	0.61*
Arka Jeet x IIHR 121	0.67*	–0.90*	–0.21**	-0.84	0.37**	–0.46*	0.15
Arka Jeet x IIHR 122	–0.28	0.25	0.22*	0.53	0.13	0.28*	0.39**
Punjab Sunehri x IIHR 616	1.02**	–0.94**	0.27**	-1.42*	–0.14	0.13	–0.03
Punjab Sunehri x IIHR 718	0.35	–0.54*	0.18	-0.07	0.33**	–0.15	0.22*
Punjab Sunehri x IIHR 190	0.12	–1.21**	–0.37**	1.65*	0.11	–0.23	–0.19
Punjab Sunehri x IIHR 121	–1.53**	1.63**	–0.17	-0.21	–0.17*	0.15	–0.23*
Punjab Sunehri x IIHR 122	0.03	0.97**	0.19	0.05	0.36**	–0.19	0.22*
RM 43 x IIHR 616	–0.62*	0.40	–0.28**	-2.52*	0.11	0.02	0.10
RM 43 x IIHR 718	–0.84**	0.29	0.23**	0.18	0.35**	0.34**	0.35**
RM 43 x IIHR 190	0.53*	0.02	0.18*	0.17	–0.11	–0.29*	–0.05
RM 43 x IIHR 121	0.70**	–0.52**	0.12	1.86*	0.32**	0.27*	0.34**
RM 43 x IIHR 122	0.27	–0.60*	–0.16	0.31	–0.17*	–0.23	–0.54**
ms-1 x IIHR 616	–0.40*	–0.71**	0.28*	1.97*	0.39**	–0.01	0.22*
ms-1 x IIHR 718	0.71*	0.63*	–0.10	-0.74	–0.12	–0.52**	–0.48**
ms-1 x IIHR 190	–0.65*	–0.58*	0.40**	2.07*	–0.18**	0.40**	–0.12
ms-1 x IIHR 121	0.58*	–0.32	–0.23**	2.43*	0.35**	0.16	0.42**
ms-1 x IIHR 122	–0.24	0.56*	–0.34**	-1.58*	–0.13	0.06	–0.04
IIHR 681 x IIHR 616	1.06**	1.30**	0.05	0.02	–0.21*	–0.68*	–0.63**
IIHR 681 x IIHR 718	1.19**	–0.52*	0.11	-0.89*	0.31*	1.22**	0.66**
IIHR 681 x IIHR 190	0.31	–0.53*	–0.26**	0.88*	0.11	–0.09	0.07
IIHR 681 x IIHR 121	–1.65*	0.65*	–0.09	0.48	–0.11	0.19	0.19
IIHR 681 x IIHR 122	–0.91**	–0.90**	–0.21**	-0.47	0.11	–0.64**	–0.29*
IIHR 352 x IIHR 616	0.02	0.15	0.21**	1.42*	–0.11	0.63**	1.01**
IIHR 352 x IIHR 718	–1.27**	–0.81**	–0.15	-0.77	0.15	0.25*	0.48**
IIHR 352 x IIHR 190	0.11	2.35**	–0.14	0.27	0.38**	–0.27	–0.05
IIHR 352 x IIHR 121	1.08**	–0.85**	0.21**	0.56	–0.18*	–0.28*	–0.85**
IIHR 352 x IIHR 122	0.01	–0.84**	0.09	-1.90*	–0.14	–0.35*	–0.68**
SE±	0.43	0.77	0.13	0.17	0.15	0.17	0.13

*, **: Significant at 5 % and 1 % probability level respectively.

^{G}SCA effects for powdery mildew and downy mildew in greenhouse house

Table 4: Economic Heterosis of Selected Five F_1 Hybrids over Check Variety NS 910 of Quantitative and Qualitative Traits in Muskmelon

	Days to First Fruit Harvest		Total Soluble Solids		Average Fruit Weight		Fruit Yield	
Hybid	Mean	(%)	Mean	(%)	Mean	(%)	Mean	(%)
Arka Jeet x IIHR 122	72.34	-8.57**	16.12	38.37**	0.72	0.01	3.63	23.06**
PS x IIHR 718	74.60	-5.72**	12.75	9.44	0.90	26.76**	3.44	16.78*
RM 43 x IIHR 718	73.85	-6.66**	14.45	24.03*	0.84	18.31**	3.88	31.52**
RM 43 x IIHR 121	75.94	-4.02**	16.40	40.77**	0.85	19.72**	4.25	44.07**
ms-1 x IIHR 616	74.85	-5.40**	14.77	26.78**	0.94	32.39**	4.15	40.68**
NS 910	79.12	-	11.65	-	0.71	-	2.95	-

*, **: Significant at 5 % and 1 % probability level respectively.

Table 5: Some Important Phenotypic Correlation between Parent and Progeny of Quantitative and Qualitative Traits in Muskmelon

	Days to Anthesis	Days to First Harvest	No. of Primary Branches per vine	Total Soluble Solids	Average Fruit Weight	Number of Fruits per vine	Fruit yield Yield
MP-Hybrid *per se*	0.73**	0.77**	0.08	0.75**	0.50**	0.64**	0.05
GCA-Parent *per se*	0.80**	0.84**	0.02	0.79**	0.60**	0.76*	0.39*
SCA-Hybrid *per se*	-0.09	0.56**	0.34*	0.35*	0.47**	0.27**	0.18*

*, **: Significant at 5 % and 1 % probability level respectively.